Every measurement is at least double, and made with currents in opposite directions.

In conclusion I may remark first, that this, like my former note, only deals with part of a larger inquiry; and secondly, that the results above stated were open to all comers, and were carefully watched by Dr. Percy Smith, Dr. Shepherd, and others of my colleagues and pupils.

W. H. STONE

THE INTERNATIONAL BUREAU OF WEIGHTS AND MEASURES[1]

As the result of an International Convention held on the 20th May, 1875, an International Bureau of Weights and Measures has been created at Paris with the object of securing an international metric system, and which should take account (1) of all comparisons and verifications of the new prototypes of the metre and the kilogramme; (2) of the conservation of the international prototypes; (3) of periodical comparisons of national standards with the international prototypes, as also of comparisons of thermometric standards; (4) of the comparisons of the new prototypes with the fundamental standards of non-metric weights and measures employed in different countries and in science; (5) of the marking and comparison of geodetical measures; (6) of the comparison of standards and scales of precision, the verification of which may be sought by governments, by learned societies, or even by mechanists and students.

An international committee of weights and measures composed of fourteen members, comprising physicists, mathematicians, surveyors, and astronomers, all of different nationalities, has been intrusted with the supreme direction of the bureau. The president of this committee is General Ibañez, director-general of the Geographical and Statistical Institute of Spain, and its secretary Dr. Hirsch, director of the Observatory of Neuchâtel. It meets once a year for the discharge of its functions at Paris.

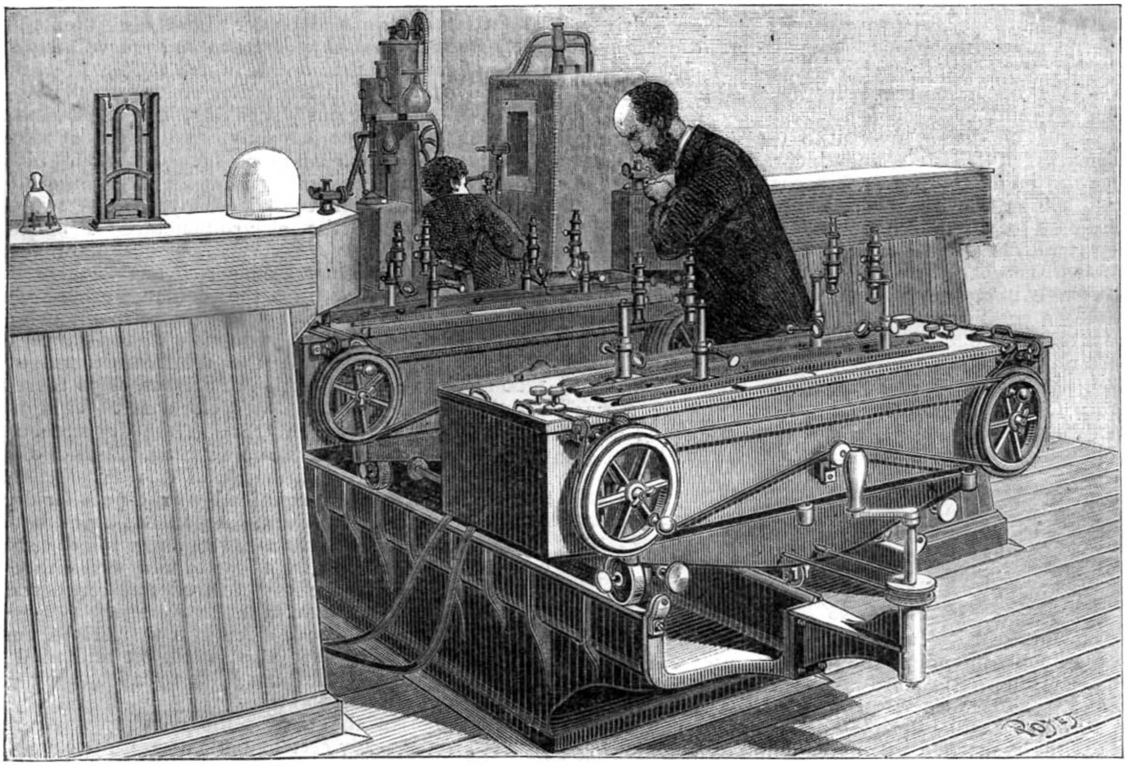

FIG. 1.—"Comparateur" for Measuring Absolute and Relative Dilatations.

Twenty States were represented at the preliminary diplomatic conference of 1875. Of these, seventeen (or nineteen) have signed the international convention which was the result of its deliberations. One alone of these States has not ratified the convention; and consequently the expenses of the foundation and maintenance of the International Bureau of Weights and Measures have hitherto been defrayed by the following sixteen States: Germany, Austria-Hungary, Belgium, the Argentine Confederation, Denmark, Spain, the United States of America, France, Italy, Peru, Portugal, Russia, Sweden, Norway, Switzerland, Turkey, Venezuela. These, representing about 351,000,000 of people, have already contributed over 1,000,000 francs towards the foundation of the International Bureau. The Government of Servia has since given in its adhesion to the convention.

In order to provide for the erection of the necessary structures for the observatory of the International Bureau of Weights and Measures, France made a grant of ground in the park of St. Cloud formerly occupied by the Pavillon de Breteuil, safely removed from all disturbances and surface tremors such as would have been experienced in the centre of a large city amidst the whirl of carriages and the working of machines.

In front of the observatory of the International Bureau are offices set apart for mechanical laboratories. Behind are spacious chambers in which are distributed the various instruments of precision employed in metrological work. These chambers are surrounded by walls of great thickness; they are lighted by skylights so arranged as to prevent solar rays from penetrating: and are environed by a lobby isolating them from the exterior. The object aimed at by these arrangements is to secure to the utmost degree possible the continuance of a uniform temperature which in certain operations is a condition of success.

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[1] From *La Nature*.

The labours of the bureau are naturally divided into two sections; one dealing with standards of length, the other with standards of mass or weight. The first comprises principally the settlement of equations of the various standards, that is of their lengths compared with the prototype which forms the universal basis of departure; the ratio of their expansions; the study of their subdivisions or of their multiples; and particularly of the great rules (*règles*) which serve geodesists for the measurement of terrestrial bases. Similarly, the section of weights is busied with determining the relations of several primary kilogrammes to the kilogramme prototype, with the adjustments of their subdivisions, with the computation of their specific weights, &c. These various labours are divided among a certain number of experts constituting the scientific staff of the bureau. We shall hastily indicate the principal instruments used in both sections, instruments which are the workmanship of the ablest mechanists in the whole of Europe, and which in general show the last limit of perfection attainable in this precise branch of mechanics.

The instruments belonging to the section of linear standards or metres, are called "comparateurs." A comparateur for metres *à traits* is essentially composed of two microscopes solidly fixed and immovable, provided with micrometers under which, by a peculiar mechanism, the two rules it is desired to compare with each other can be successively introduced. The bureau possesses several of these instruments, each adapted to a special purpose, and consequently distinguished by peculiarities of construction.

The first is Brunner's comparateur, designed for comparisons in air of metres *à traits*. The two microscopes are by means of cantilevers riveted on large stone pillars or monoliths resting on massive masonry. The micrometers with which they are furnished follow the arrangements usually observed in the case of astronomical instruments. Each is composed of a kind of little rectangular box, lengthened and flattened, fixed on the body of the microscope below the eyepiece. In this box is a frame capable of being displaced from right to left. On the frame are stretched two spider threads, very fine, parallel and very close to each other, which constitute the parallel spider threads or reticule. The displacement of the frame is effected very slowly by means of a micrometer screw of perfect workmanship, which is worked from the outside by means of an enlarged micrometer-head or drum, the circumference of which is divided into a hundred equal parts. By turning this round the experimenter moves the screw, which in turn moves the frame and displaces the spider threads visible in the field of the microscope. The image of the lines traced on the rule as given by the objective then lies in the plane of these threads. To bisect a line is to make the parallel threads coincide with the image of this line, that is by turning round the drum so as to bring the threads into such a position that the line may appear exactly in the middle of them; the position occupied by the parallel threads will in that case be indicated by the reading of the micrometer-head or drum. Should a second line appear under this microscope in a different position, it will be necessary, in order to bisect it in turn, to displace the threads, that is to make the drum revolve a certain number of divisions. The distance corresponding with one displacement of a division being known, the distance between the first and second lines can then be calculated.

Under the microscopes is the body itself of the comparateur, composed primarily of a strong framework of brass, exceedingly massive and steady, forming on its upper borders a kind of railway on which rolls a heavy carriage, movable at pleasure by a handle which controls a system of cog-wheels. Surmounting this carriage is a long box or metal trough with double walls formed of two cases inclosed one within the other. This box is designed to receive the two rules that are to be compared. These are placed beside each other in the middle of the box on supports of suitable form. The box is provided with various contrivances by means of which the observer, while observing the microscopes, is able to adjust the rules; to lower them or to raise them; to bring them into focus at the two extremities, or to displace them longitudinally or transversely, as may be required. The box is able, moreover, to receive a sufficient number of thermometers, which are observed with the aid of special lenses fitted in the lid which covers the whole and which

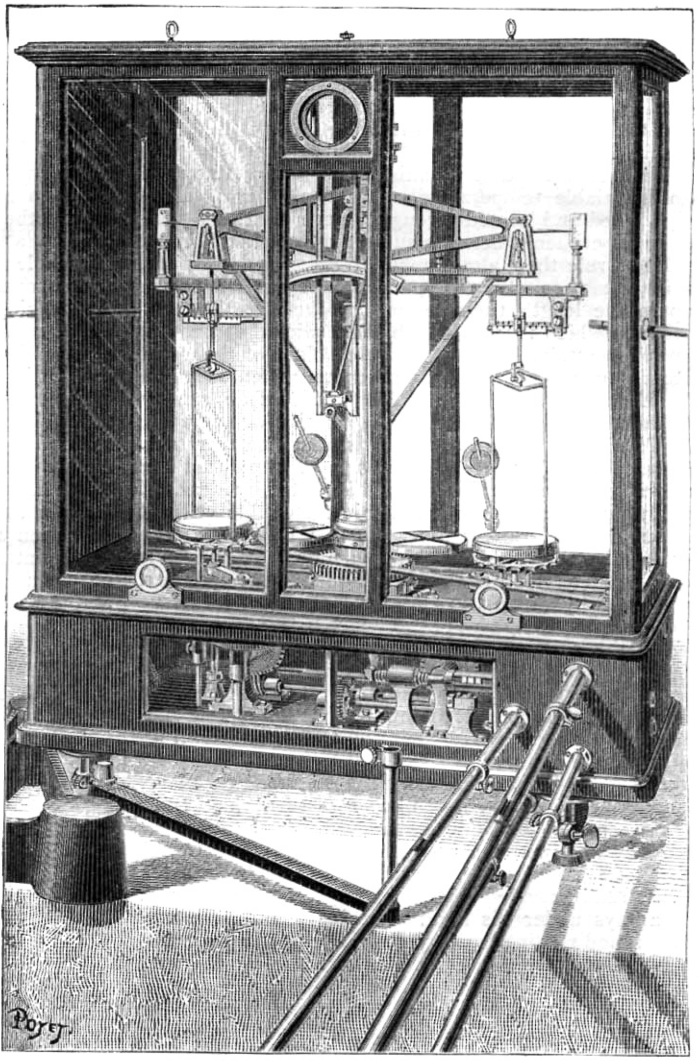

Fig. 2.—Balance of Precision for Comparison of Standard Kilogrammes.

protects the interior of the apparatus from every rapid variation of temperature. By the movement of the carriage the observer brings successively under the microscopes, the two metres the difference between which he wants to ascertain; he bisects the lines of both, and this operation made at the two extremities furnishes the equation desired between the two rules.

Another of the comparateurs represented in the accompanying diagram (Fig. 1) is designed for the measurement of expansions. As in the preceding comparateur we here also find two microscopes with fixed micrometers and a carriage moving on rails. Here, however, the carriage contains two distinct boxes or troughs; each at a distance of about one metre from the other. The two rules to be compared are placed one in each of these troughs. They are thus to some extent independent of each other, and may therefore be introduced at different temperatures. To measure the expansion of one rule, you place it in one of the troughs, and in the other trough the other rule called "*de comparaison*." This latter, so long as the process of determination lasts, is maintained at an invariable temperature, while the other is alternately cooled and heated throughout the series of consecutive experiments between sufficiently extended limits. The latter rule then alternately contracts and expands, and in the case of each particular experiment you compare the length the rule has reached at the temperature to which it is then subjected, with the constant length of the "*de comparaison*" rule. One of the great difficulties connected with these measurements is the maintenance for a sufficiently long time of an exactly uniform temperature, particularly when this temperature is notably at variance with the surrounding temperature. To secure this requirement the rules to be compared are immersed in a liquid, and this liquid is heated by means of a constant circulation of water within the double walls of the trough. Indiarubber pipes, as may be seen in the diagram (Fig. 1), are used for this purpose. The water is supplied from a large metal reservoir outside the chamber, being heated by a regulating system that causes it to issue at an invariable temperature. Thence by pipes it is conveyed to the comparateur, traverses the trough in a continuous stream, and is then carried off by waste pipes, conveniently arranged, into a drain. By this means a constant thermal state is maintained, within a few hundredths of a degree, at any point up to forty degrees, for whole hours at a time.

The diagram (Fig. 1) indicates the principal details of the mechanism employed. In front is seen the handle which by means of an endless cord draws away the carriage and allows the rapid substitution of one trough in place of the other under the microscopes. On the sides, the long rods provided with buttons, which the observer finds always under his hand whatever position he may occupy round the instrument, have the power of acting equally on the carriage by means of a cog-wheel placed under it, and of moving it backwards and forwards by a uniform slow movement. On the lids are perceived the heads of the different keys which enable rectifications of all adjustments to be made, as also the lenses by means of which the thermometers are read. The fly-wheels placed in front of the troughs serve by means of cords and pulleys to convey a movement of rapid rotation to the agitators which are placed in the trough, and thus vigorously intermingle the strata of the liquid, and secure uniformity of temperature in all parts of the bath.

With these apparatuses the difference can be determined between two metres at a given temperature with an exactness reaching to some ten-thousandths of a millimetre. In order to obtain such nicety, it is of course necessary that the lines of the metres be traced with sufficient fineness and distinctness to fit them for the magnifying power employed.

The two instruments just mentioned are fitted for the comparison of metres alone. The *comparateur universel*, on the other hand, allows comparisons to be made of any lengths whatever from below a metre up to two metres. The aspect of this new comparateur is entirely different from that of the two preceding. The microscopes which in all cases constitute the essential parts, instead of being fixed, are here mounted on carriages, which can be moved over a kind of bridge placed horizontally between two stone pillars. This bridge is formed by a large block of brass furnished with steel surfaces on its upper edges, which serve as a support and guide to the microscopes in their movements. It is perfectly rectilineal and horizontal When, by moving the carriages, the microscopes have been brought into the position they require to occupy for a given work, they are fixed by tightening a lever with the aid of a knob which controls a screw. Below, as in the preceding comparateurs, is a massive carriage likewise bearing supports on which are arranged the rules needing to be examined. These supports are equally furnished with all the necessary means of adjustment. These latter, again, are worked by a mechanism too complicated to allow so much as an idea of it to be communicated without the help of diagrams. The comparateur contains, besides, a standard rule of two metres, divided along its whole length into centimetres, two supplementary microscopes mounted on a special carriage and designed for marking the subdivision of a metre, various accessory pieces capable of serving for comparison of measures *à bouts*, either one with another or with measures *à traits*,[1] &c. It is entirely inclosed in a large mahogany box. This box is furnished with windows necessary for lighting the various parts, and with the orifices required for the transmission of movements to the interior, &c., and has the appearance of an imposing and elegant piece of furniture.

We have still to mention a comparateur for metres *à bouts* by Steinheil's method; and to add that this beautiful collection will in the course of a few months be completed by the introduction of a geodetical comparateur for rules of four metres, which is actually in process of construction, and the object of which is indicated by its name.

(*To be continued.*)

THE VIENNA INTERNATIONAL ELECTRIC EXHIBITION

FOR two weeks, the arrangement of the machinery being nearly complete, the Exhibition has been open in the evening from 7 till 11. The effect of the illumination of the immense interior of the Rotunda and its annexes by the various incandescent and arc lamps, and of the surrounding places which are lighted by large reflectors, is brilliant. The electric railway of Siemens and Halske between the Rotunda and the Praterstern is already in operation. The theatrical performances at the "Asphaleia" Theatre, which is lighted by 1500 Swan lamps fed by a large Zipernowsky alternating current machine, have also begun this week.

The series of lectures to be held at the theatre during the Exhibition was inaugurated on August 27 by Sir C. W. Siemens, with a lecture "On the Temperature, Light, and Total Radiating Power of the Sun." After a short introductory sketch of the nature of the terrestrial sources of light, the lecturer gave an account of the ratio of the three forms of radiant energy, viz. heat, light, and actinism, as produced by the sun and terrestrial light sources. Then referring to the difference between the statements of various astronomers and physicists relating to solar temperature, he expressed his opinion that the temperature of the sun could not exceed 3000° C., and explained the experimental methods he used for measuring the solar temperature. The second lecture was delivered on Sep-

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[1] A metre or other measure *à bouts* is one whose ends exactly coincide with the ends of the material of which it is made; a measure *à traits* is bounded by lines within the margins of the material on which it is traced.